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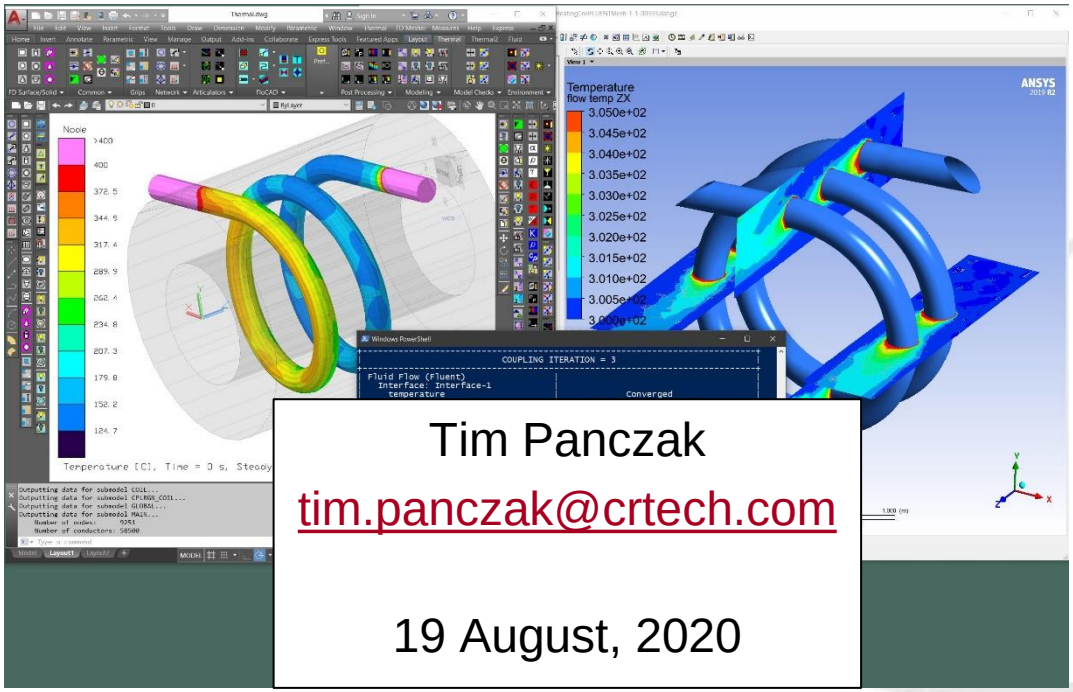
Co-solving 3D Fluid Flow and Heat Transfer with CRTech Thermal Desktop and ANSYS Fluent



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19 August, 2020

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Agenda

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- Motivation
  - Applications
- Overview
  - Architecture
  - User process
- Example
  - Kegerator
- Work in progress
  - FloCAD <-> Fluent coupling

Motivation

- Provide 3D flow solver integrated with CRTech simulation products
  - Conjugate Heat Transfer with Radiation and 1D Fluid Flow
    - Will be released with Version 6.2
  - *Work in progress:* Coupling 1D and 3D fluid flow
    - FloCAD <-> Fluent
- Partnership with ANSYS since 2018
  - Outstanding support and project facilitation
  - Longer term ideas for Workbench/Mechanical integration

Applications

- Cryogenic tanks
- Aeroheating
- Regenerative cooling for nozzles
- Ground service cooling
- Crew comfort
- Green building design
- Turbomachinery

ANSYS System Coupling

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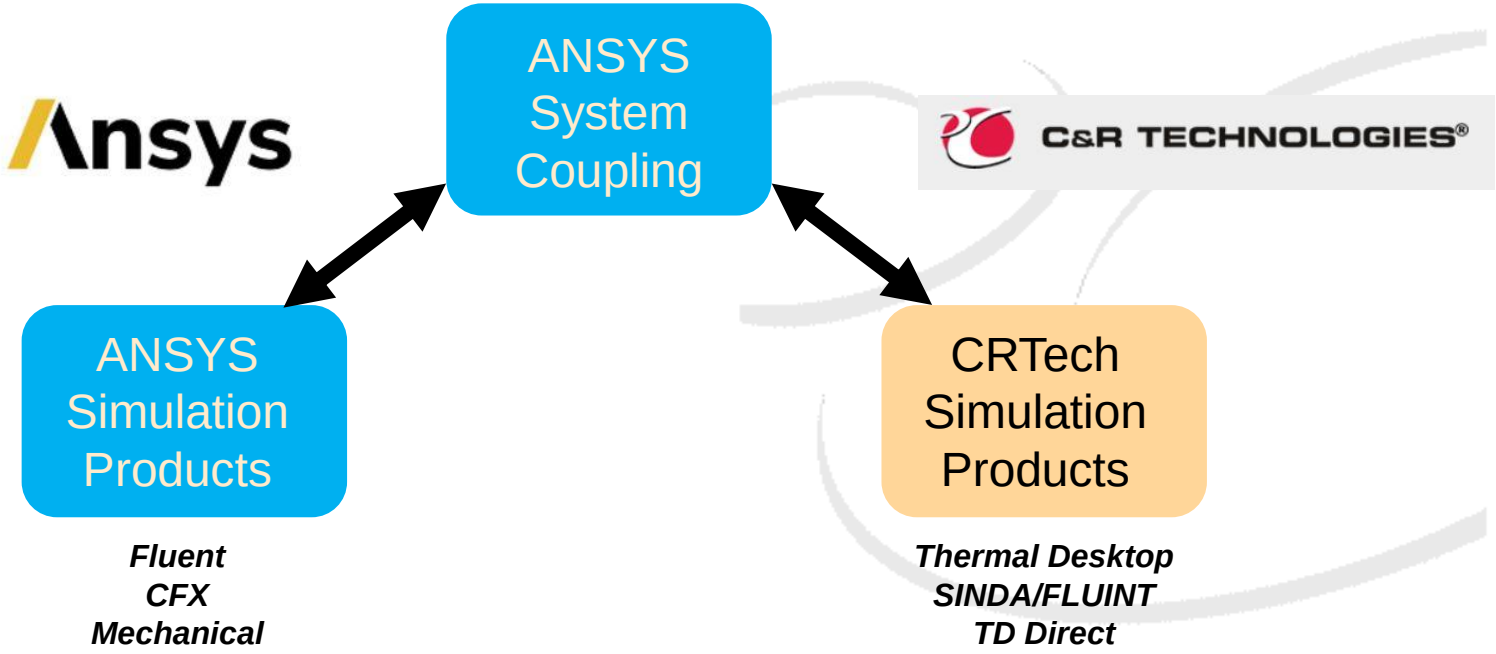
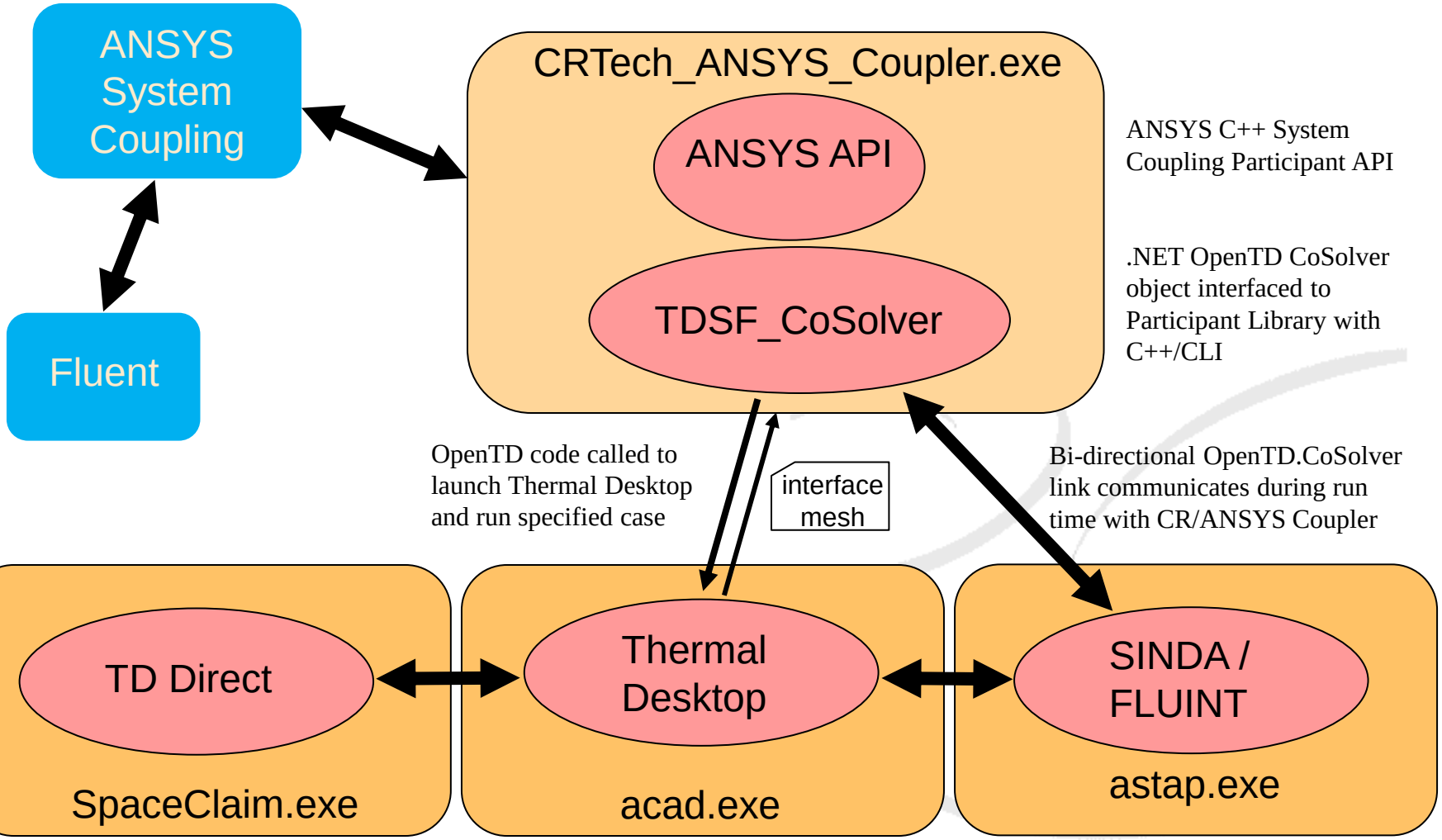
- Platform for integrating 3rd party applications with ANSYS simulation products
  - Coordinates co-simulation of two or more “participants”
    - Launches participants, synchronizes data transfers
  - API provided to connect with System Coupling
  - GUI or script driven



Participant Implementation
ANSYS API + OpenTD



Features of ANSYS System Coupling

- Transient, Steady State, and Pseudo-Transient
  - Either participant can be steady or transient
- Interface coupling options
  - Fluent supplies Heat Flux - SINDA/FLUINT supplies Temperature
    - Q-T (Neumann-Dirichlet)
  - Convection Coefficient/Fluid Reference Temperature – Temperature
    - Hconv/Tref – T
  - Interface Quasi-Newton Least Squares stabilization
  - Under-relaxation and ramping
  - Coordinate transformation of models
- Postprocessing and debug tools
- Distributed processing
- Restarts
- GUI or command line

Steps to Setup Analysis

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- Create working directory and System Coupling input file
- Place Thermal Desktop surface elements in the domain “Coupling_Region”
- Set Fluent interface zones to “Via System Coupling”
- Add a single line to OPERATIONS to setup communications with CRTech_ANSYS_Coupler
- Run System Coupling

Working Folder

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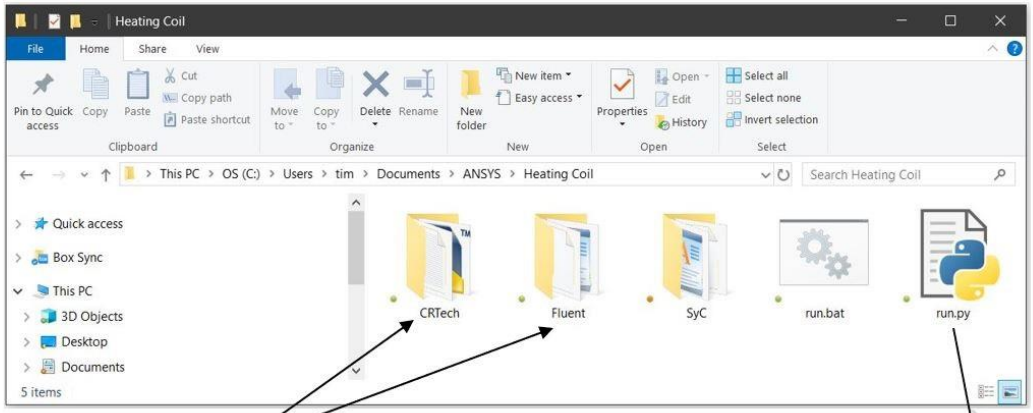
- Place Thermal Desktop and Fluent working directories under a System Coupling working directory



Create subfolders for each participant.

Modify run.py as needed.

The batch file run.bat launches ANSYS System Coupling which will then automatically read the input script, run.py.

The “SyC” folder will be created by ANSYS System Coupling.

```
import os
import platform

# Set up and run SC case

# Load the Fluent SCP file.
AddParticipant(InputFile = '.\\Fluent\\fluent.scp')
AddParticipant(InputFile = '.\\CRTech\\crtech.scp')

# Add CR Tech participant to the datamodel manually.
dm = DatamodelRoot()
crTechSolver = dm.CouplingParticipant['DEFAULT-2']
crTechSolver.DisplayName = 'CR Tech Solver'

# Specify CR Tech Solver executable
crTechExe = '"C:/Program Files/Cullimore and Ring/Thermal Desktop/CRTechSolverWrapper.bat"'
crTechSolver.ExecutionControl.Executable = crTechExe
crTechSolver.ExecutionControl.WorkingDirectory = './CRTech'
crTechSolver.ExecutionControl.AdditionalArguments = ' --dwg Thermal.dwg --case "Case Set 0"'
```

Create Domain “Coupling_Region”

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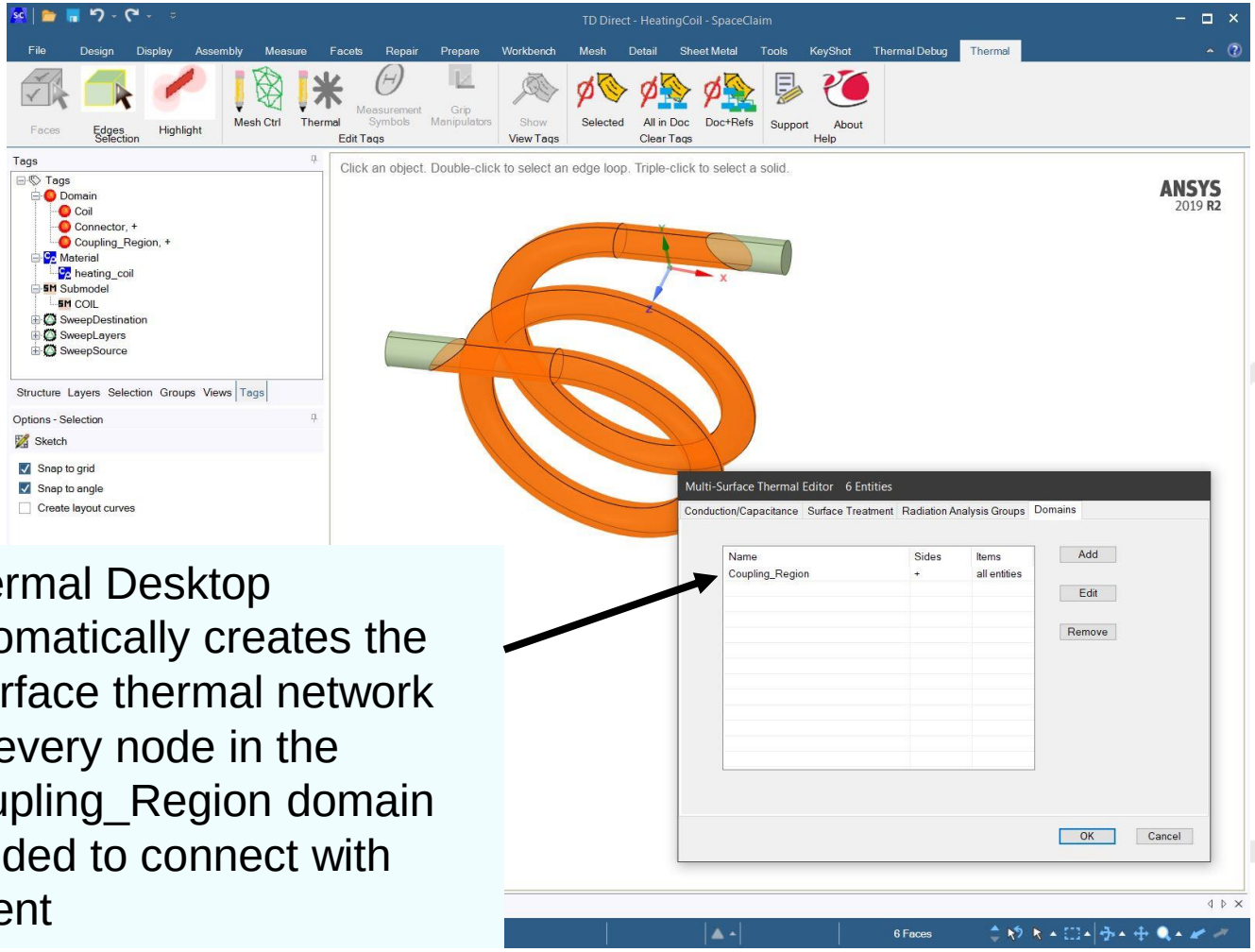
TD Direct / Thermal Desktop



Thermal Desktop automatically creates the interface thermal network for every node in the Coupling_Region domain needed to connect with Fluent

Set Wall Zone BC to "Via System Coupling"

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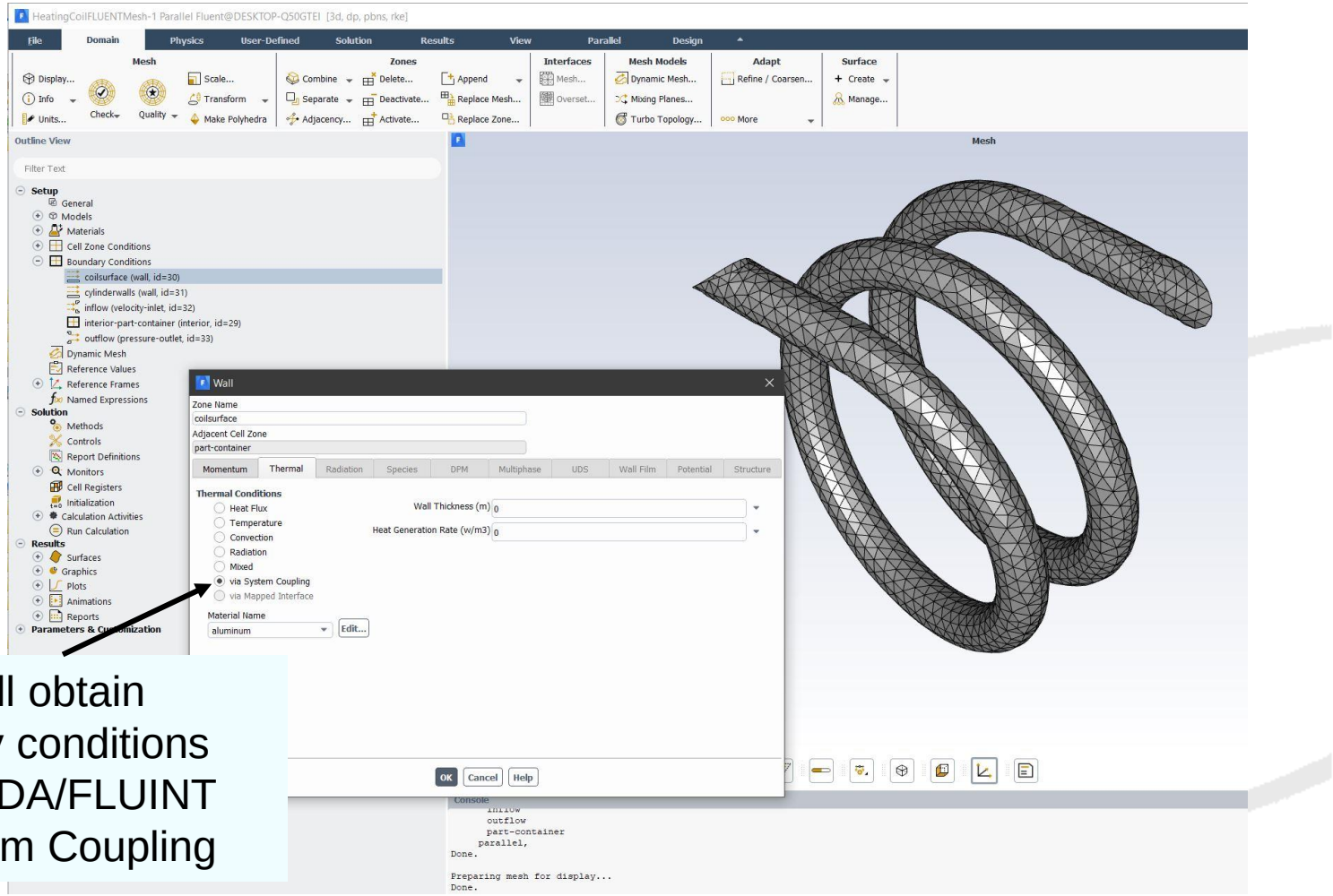
Fluent



Fluent will obtain boundary conditions from SINDA/FLUINT via System Coupling

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SINDA/FLUINT OPERATIONS BLOCK

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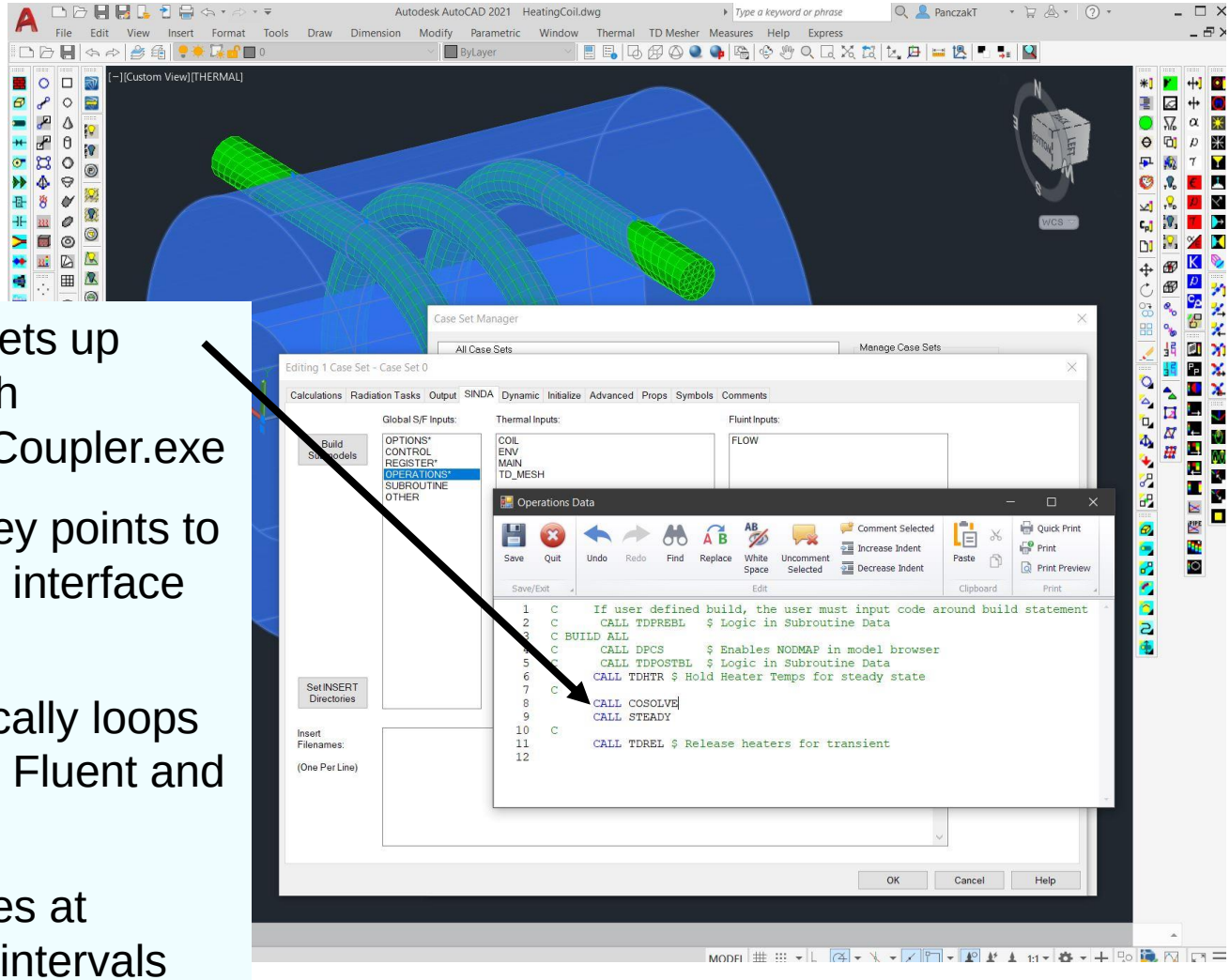

CALL COSOLVE sets up communication with CRTech_ANSYS_Coupler.exe

S/F will pause at key points to supply and receive interface data

STEADY automatically loops internally until both Fluent and S/F are converged

TRANSIENT pauses at coupling step time intervals

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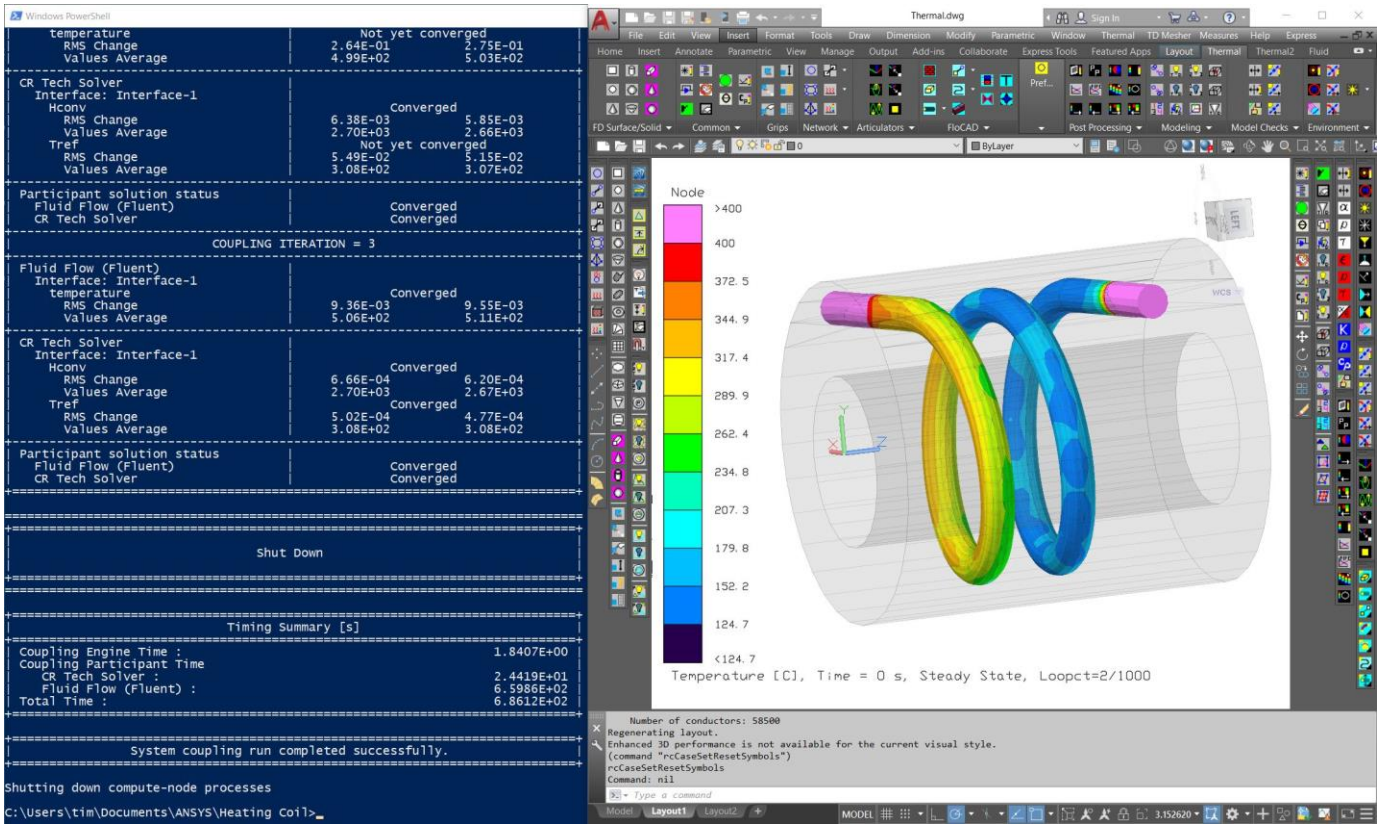
Run System Coupling

System Coupling will launch Fluent and the CRTech-ANSYS coupler

CRTech ANSYS coupler will set up communication pipes, launch TD, and then run specified Case Set

S/F will communicate with System Coupling to supply and receive interface data



Interface Postprocessing

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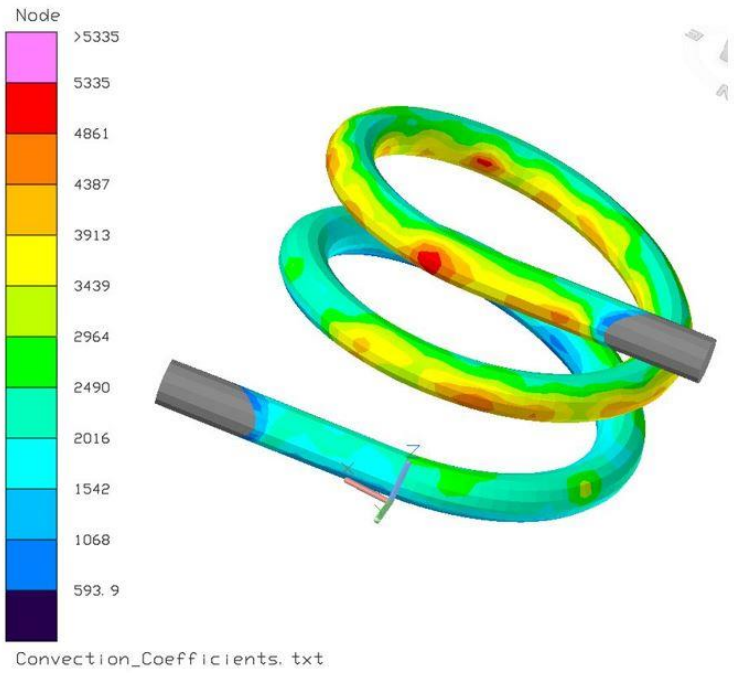
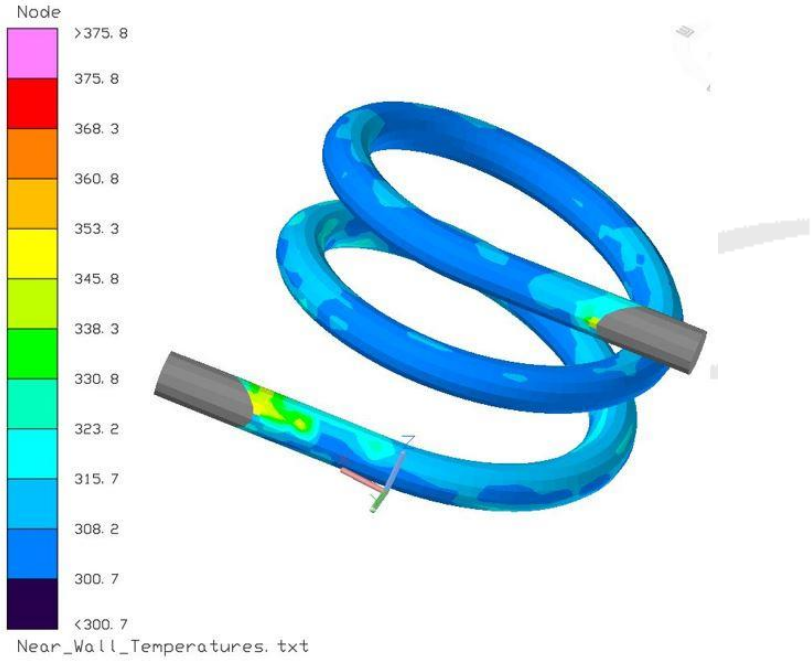
Convection coefficients, heat flux, and near wall fluid temperatures from Fluent can be displayed





Example Kegerator Model

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- A more complicated model was developed to showcase a number of ANSYS and CRTech analysis capabilities
  - Fluent internal convection
  - Thermal Desktop thermal modeling
  - RadCAD internal IR radiation exchange
  - FloCAD refrigeration cycle
  - FloCAD Compartments for keg contents, including CO2 dissolution and evolution
  - FloCAD network for dispensing system
  - Detailed FEM with system level abstract modeling
- A fun model, but also similar to many aerospace tank and piping issues

SpaceClaim Geometry

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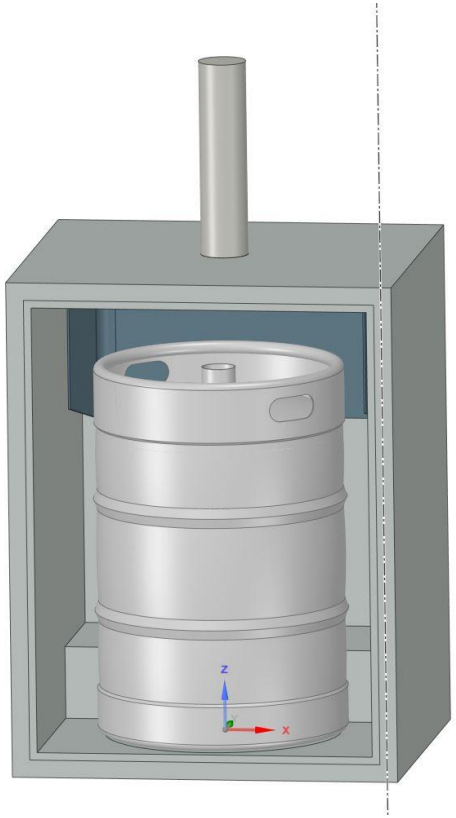
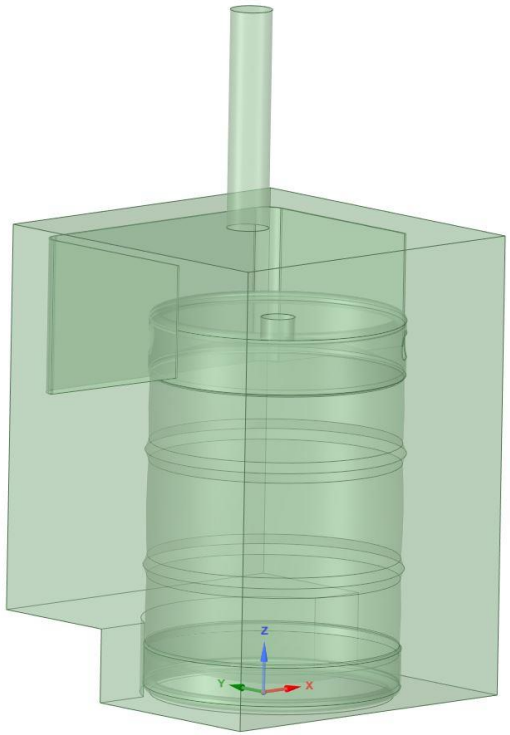
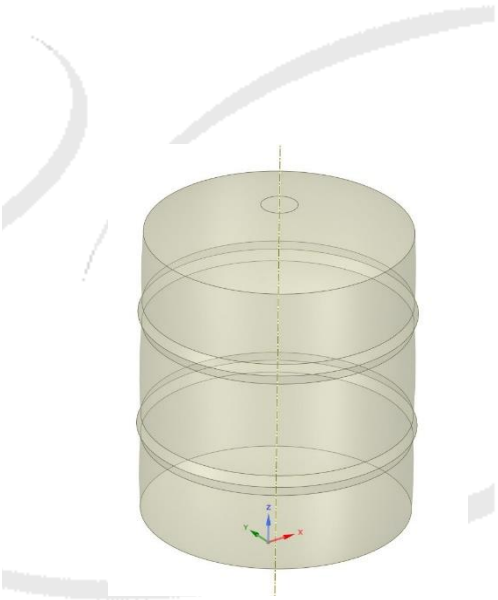
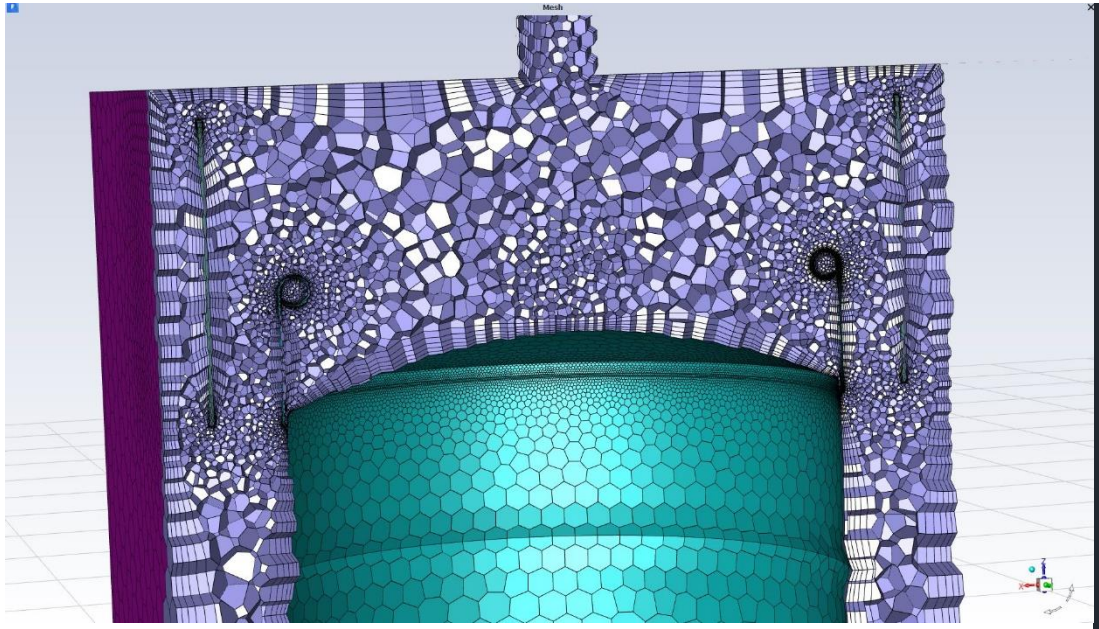
- Separate SpaceClaim documents for kegerator, keg, Fluent internal volume and FloCAD Compartment volume were created

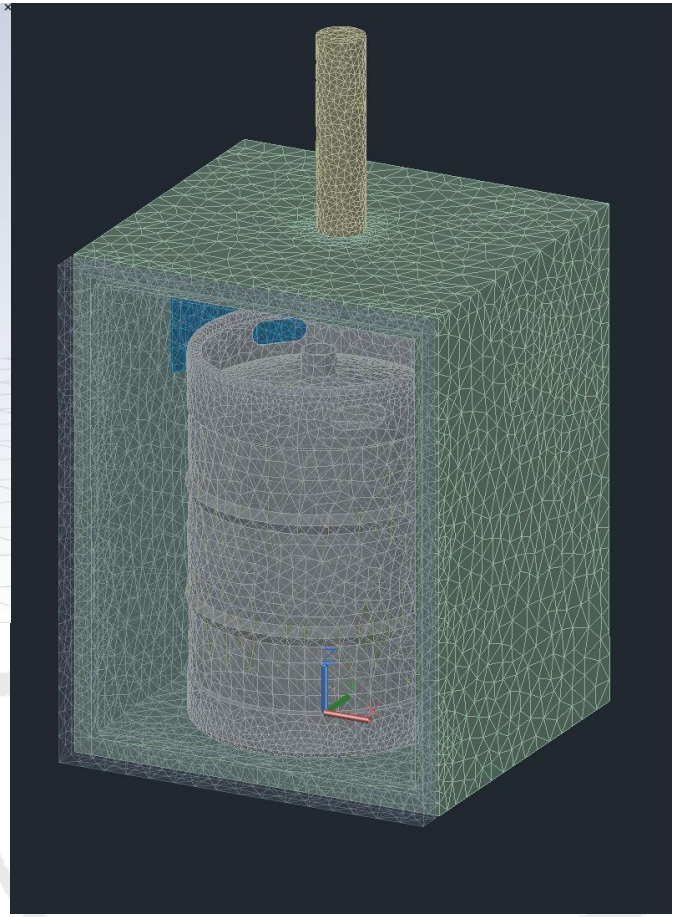






Meshes





Fluent used for fluid mesh, TD Direct for thermal mesh

Meshes at fluid/structure interface do not have to be conformal

System Coupling performs a mapping process to map data from one side of the interface to the other

System Coupling Debug Tools

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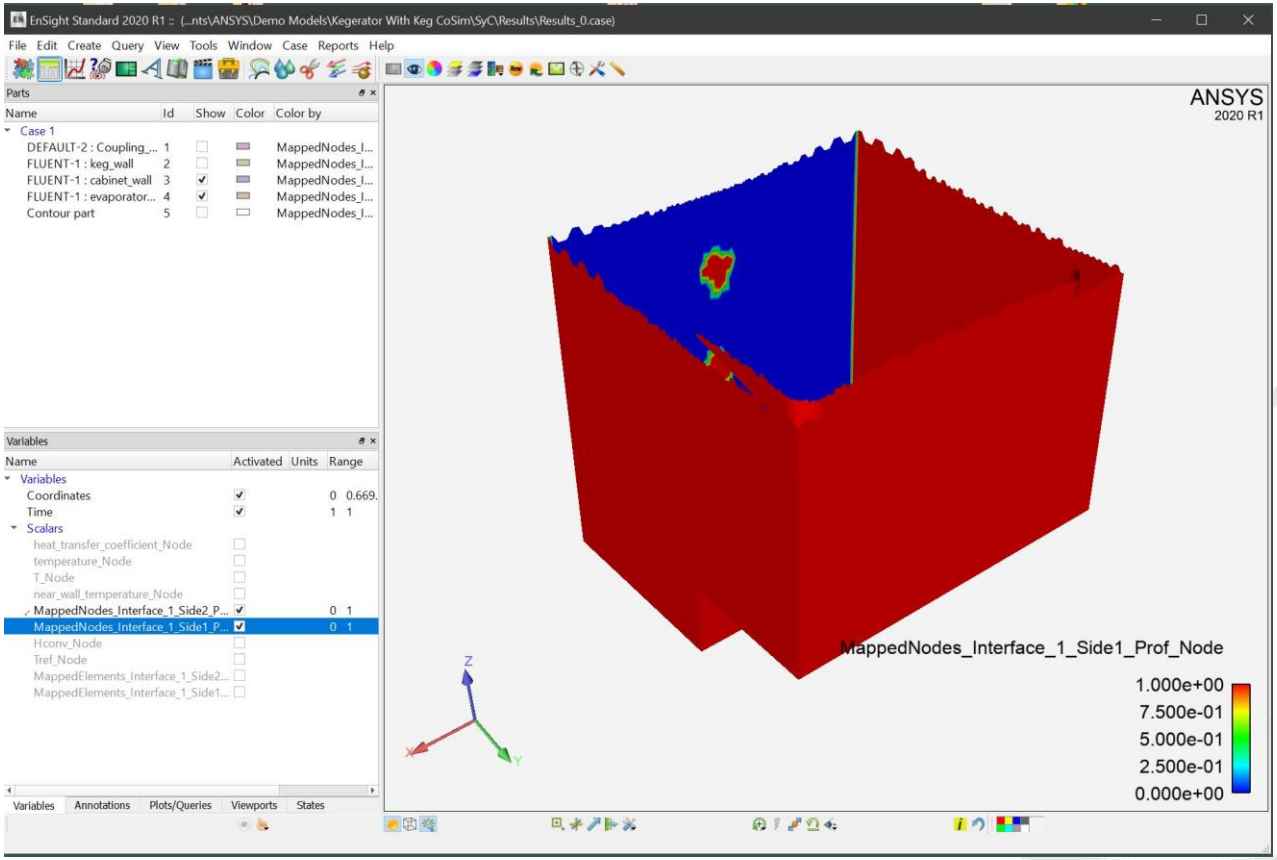
- Mapped element success



Test Model Characteristics

- Difficult model for CHT problems
  - Natural convection can significantly change flow pattern as solution converges
    - Not always asymptotic convergence
  - Biot number greater than one in some areas
    - Q-T method is unstable
    - Hconv/Tref-T is robust but slow, most common
- Interface Quasi-Newton Least Squares method successfully employed
  - Relatively new approach
  - Applied to Q term supplied by Fluent

Results using Q-T Coupling Method

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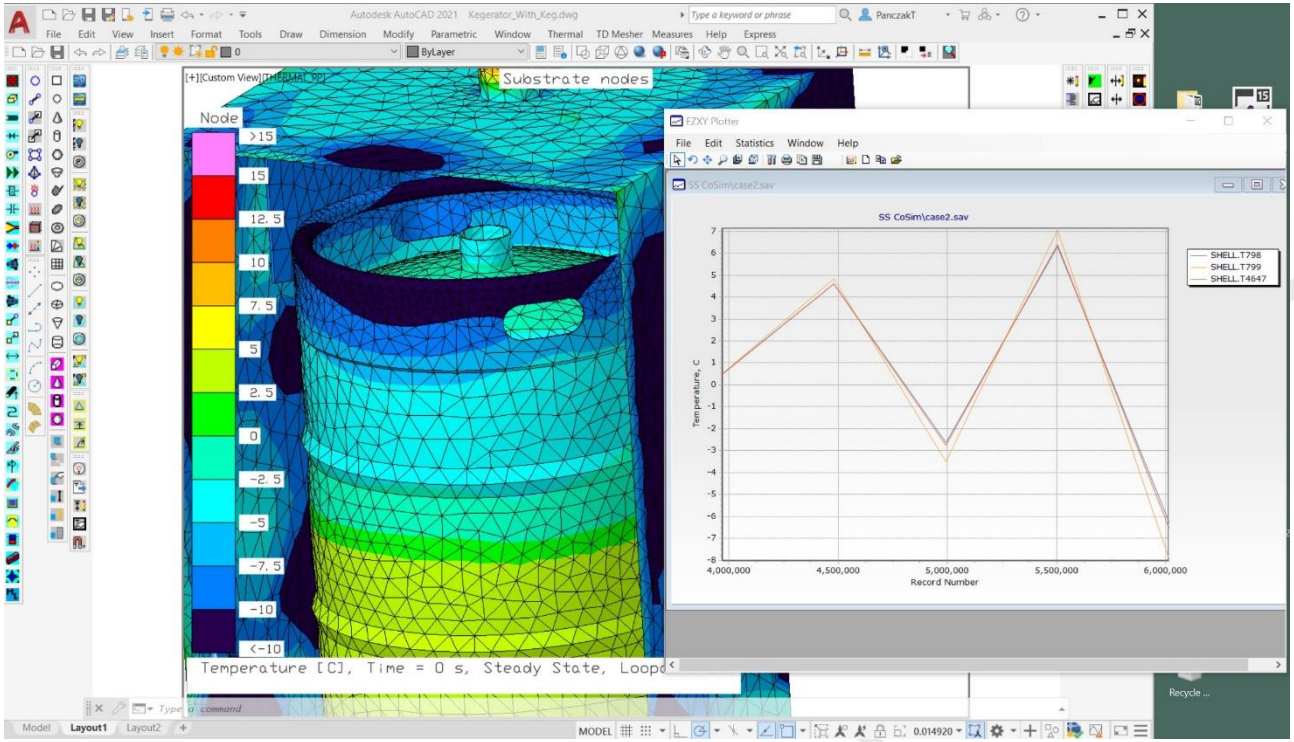
Unstable



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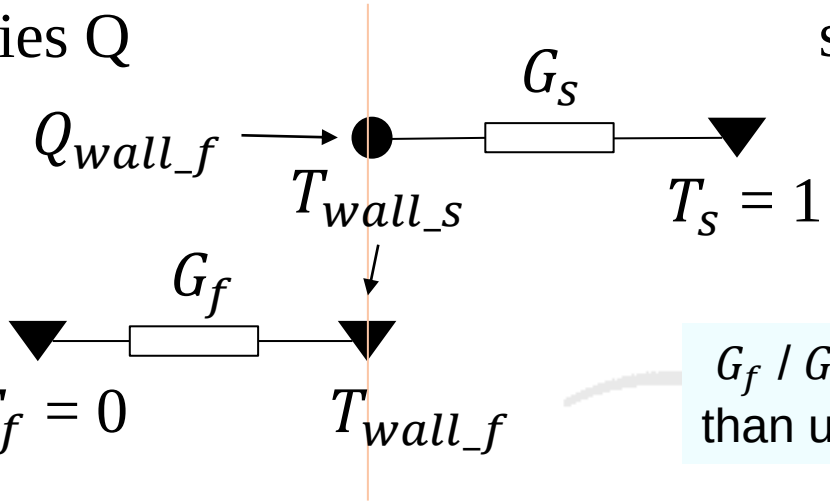
Simplified Network View
Q-T Method Example

Fluid side supplies Q

Solid side supplies T



G_f / G_s must be less than unity for stability

Iterative process:

$$T_{wall\_f} = T_{wall\_s}$$

$$Q_{wall\_f} = G_f(T_f - T_{wall\_f})$$

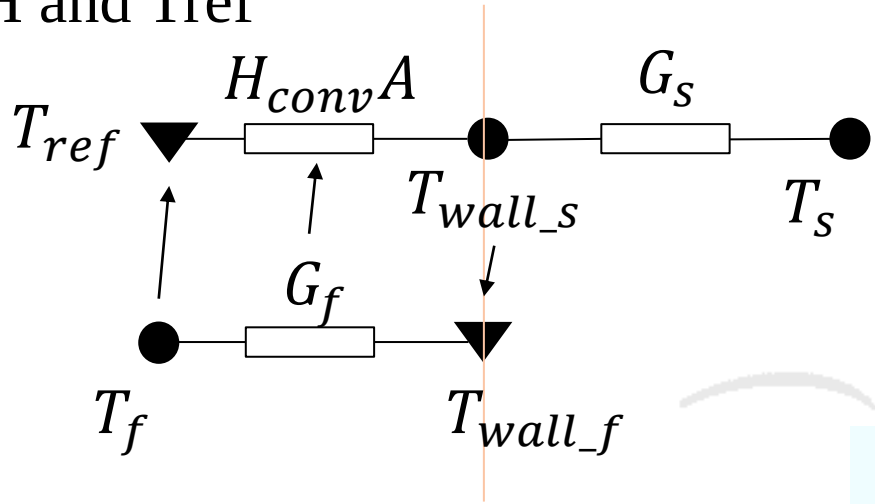
$$Q_{wall\_s} = Q_{wall\_f}$$

$$T_{wall\_s} = (G_s\, T_s + Q_{wall\_s}) \;/\; G_s$$

Simplified Network View H/Tref – T Method

Fluid side supplies H and Tref

Solid side supplies T



G_f / (G_s + G_f) is always less than one

Iterative process:

$T_{wall\_f} = T_{wall\_s}$

$H = G_f/\mathrm{A}$

$T_{ref} = T_f$

$T_{wall\_s} = (G_s T_s + G_f T_{ref})$ / (G_s + G_f)

Results Using Hconv/Tref – T Method

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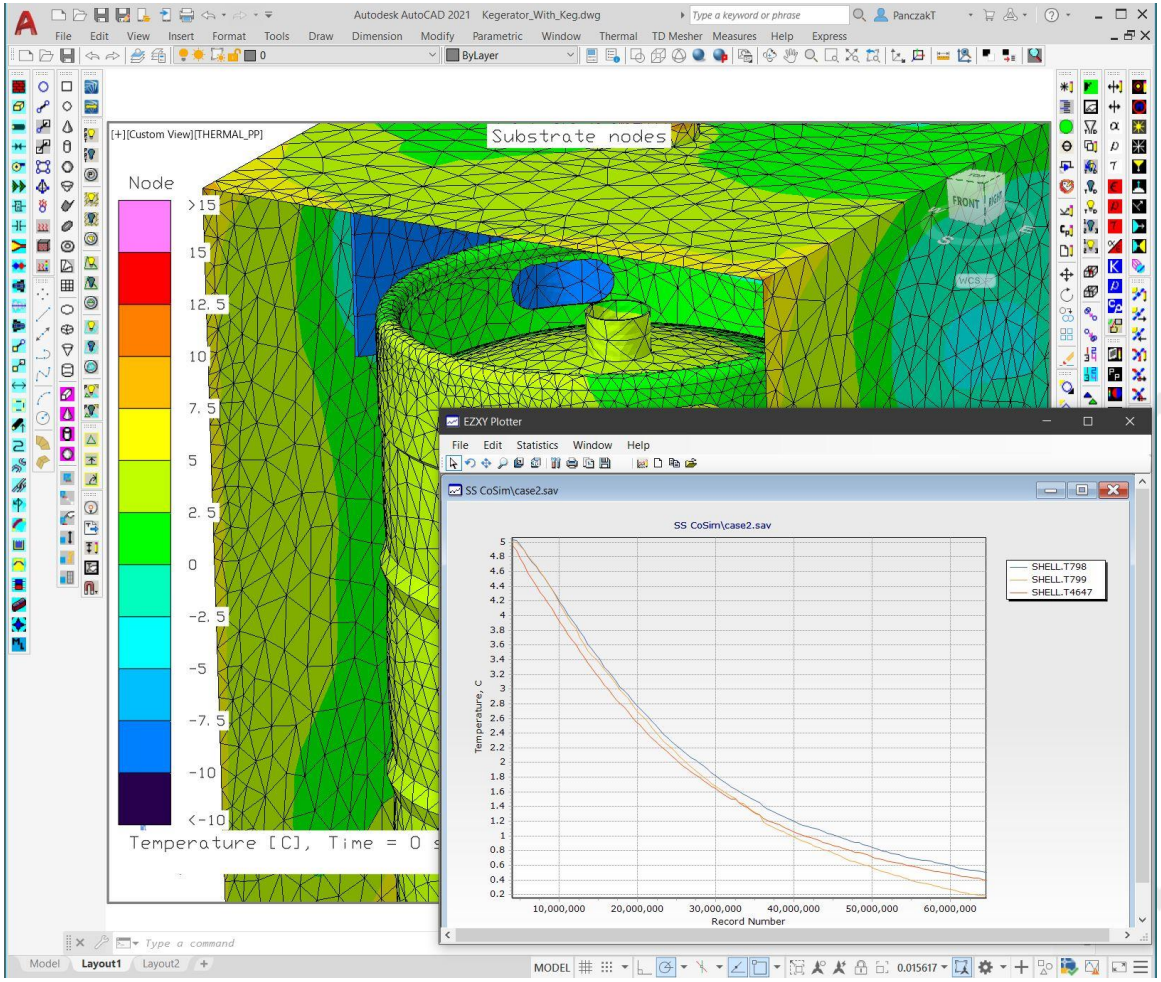
Stable, but very slow. Not converged after 120 iterations.



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Results Using Q-T Stabilized with IQN-LS

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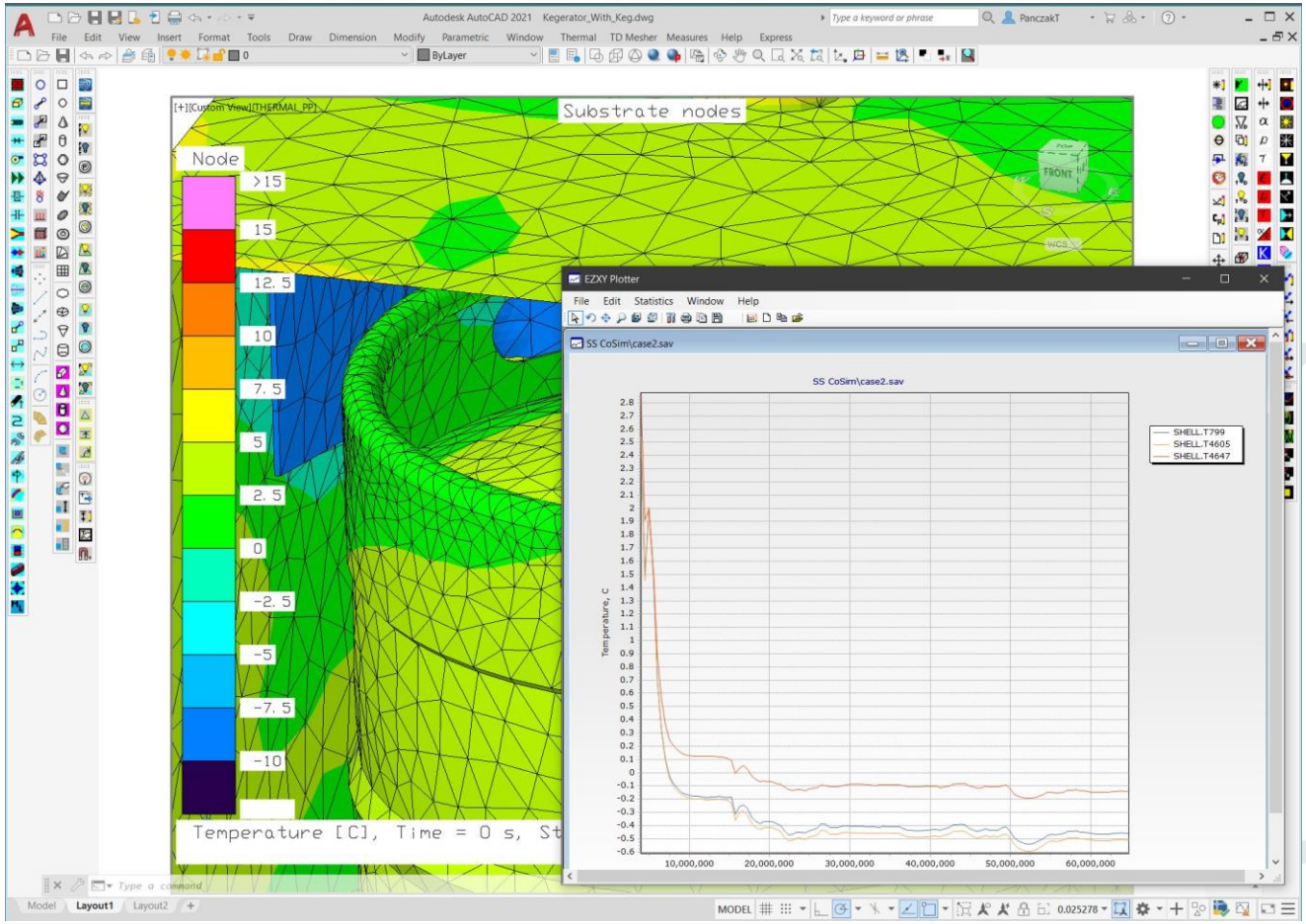
Stable, and fast!



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Thermal Desktop Results

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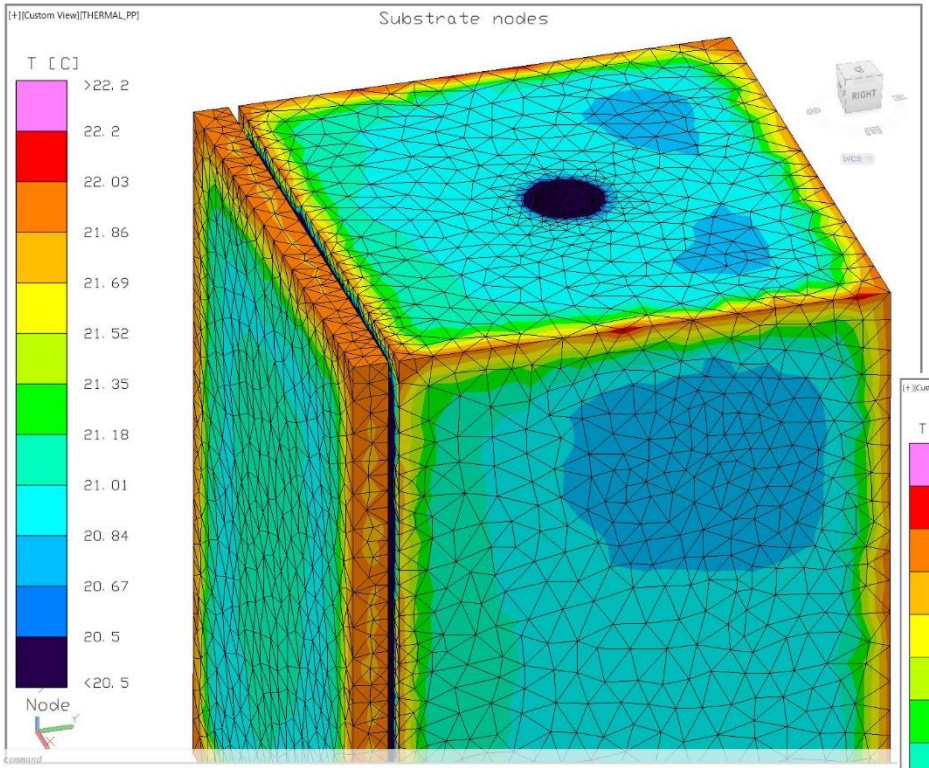
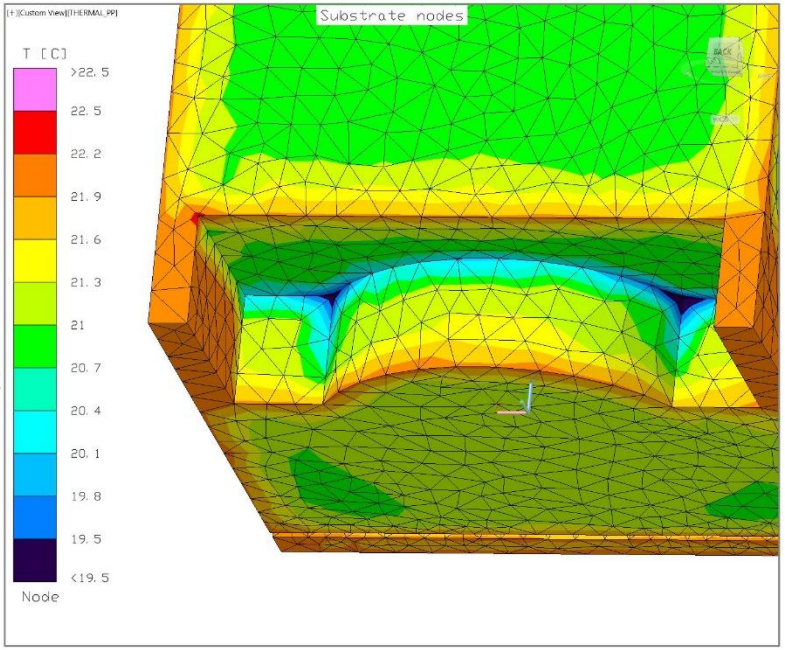


Cabinet exterior top view

Cabinet exterior bottom view



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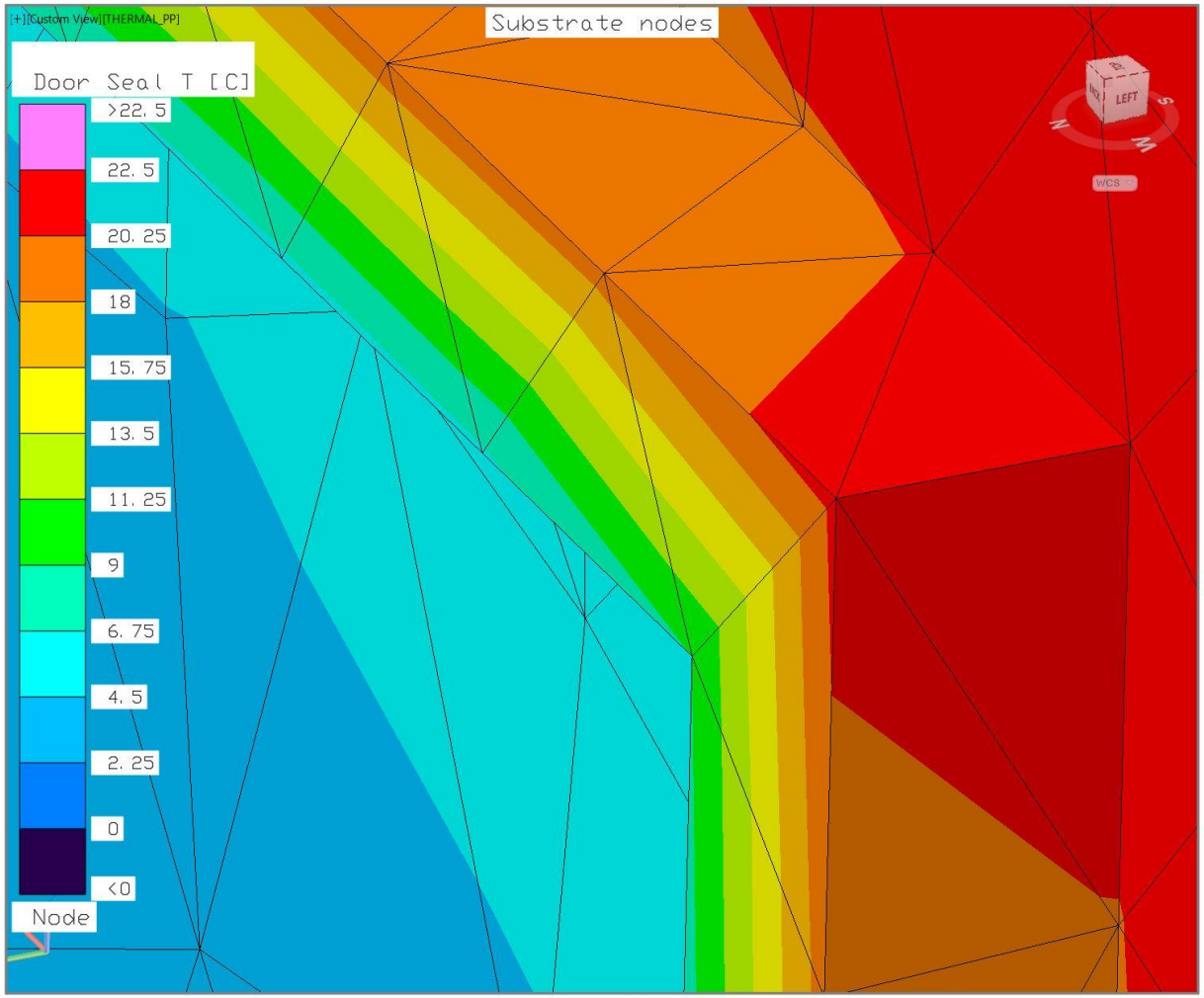
Thermal Desktop Results



Door Seal

Thermal Desktop Results

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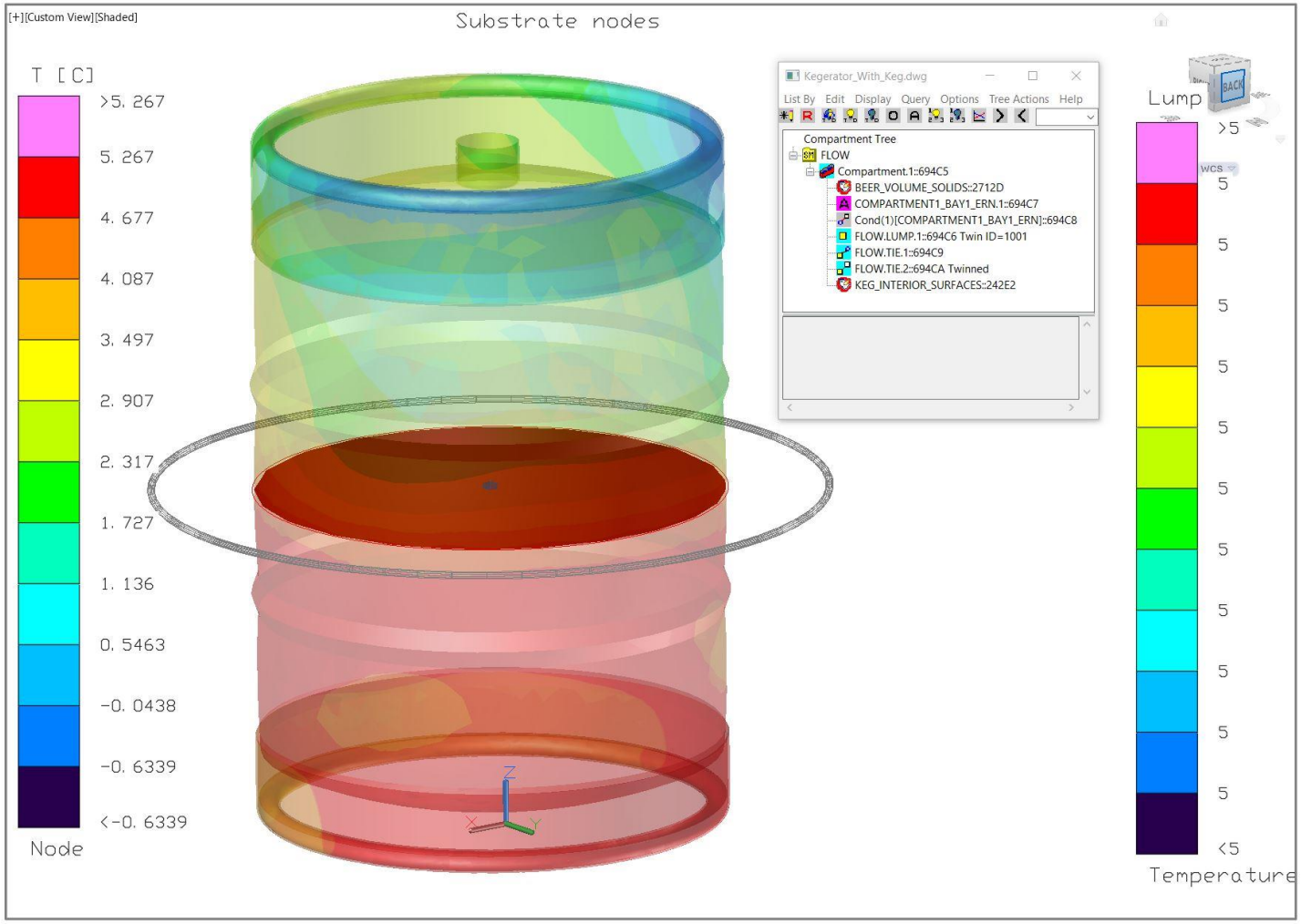

FloCAD Compartment showing liquid level inside keg

Thermal Desktop Results

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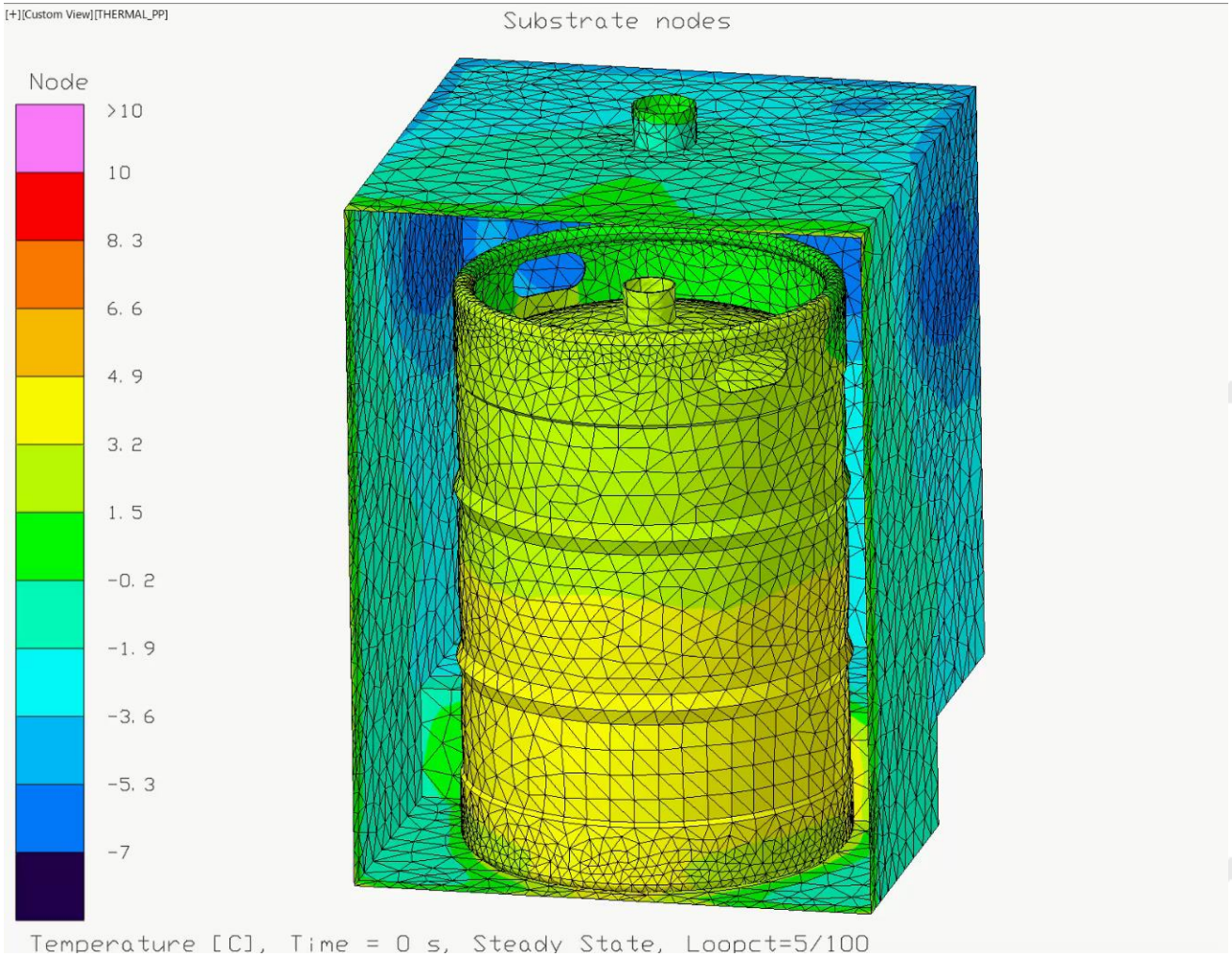
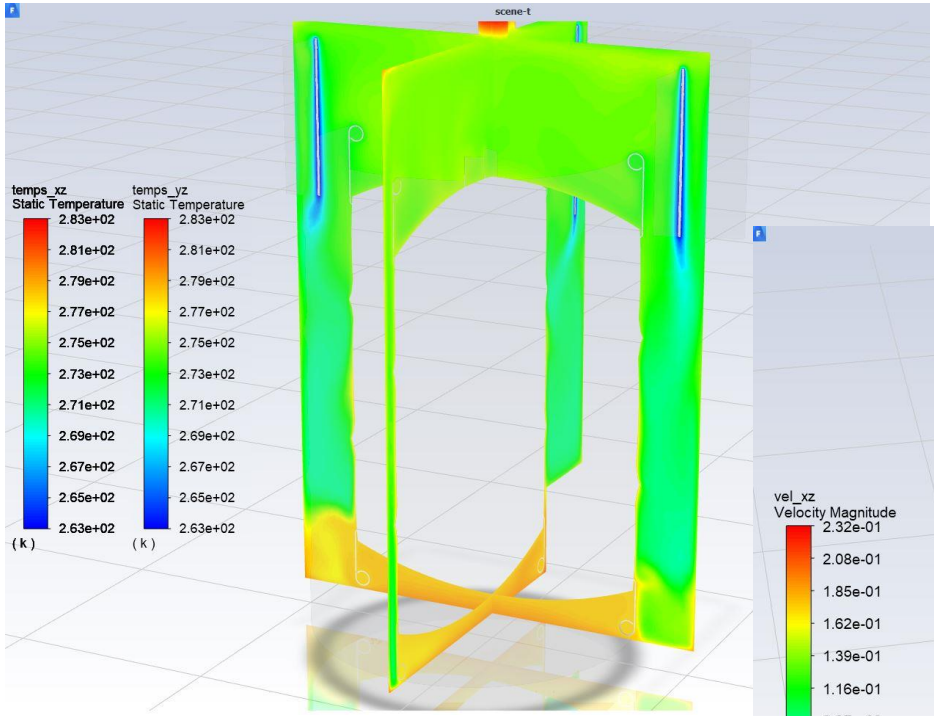
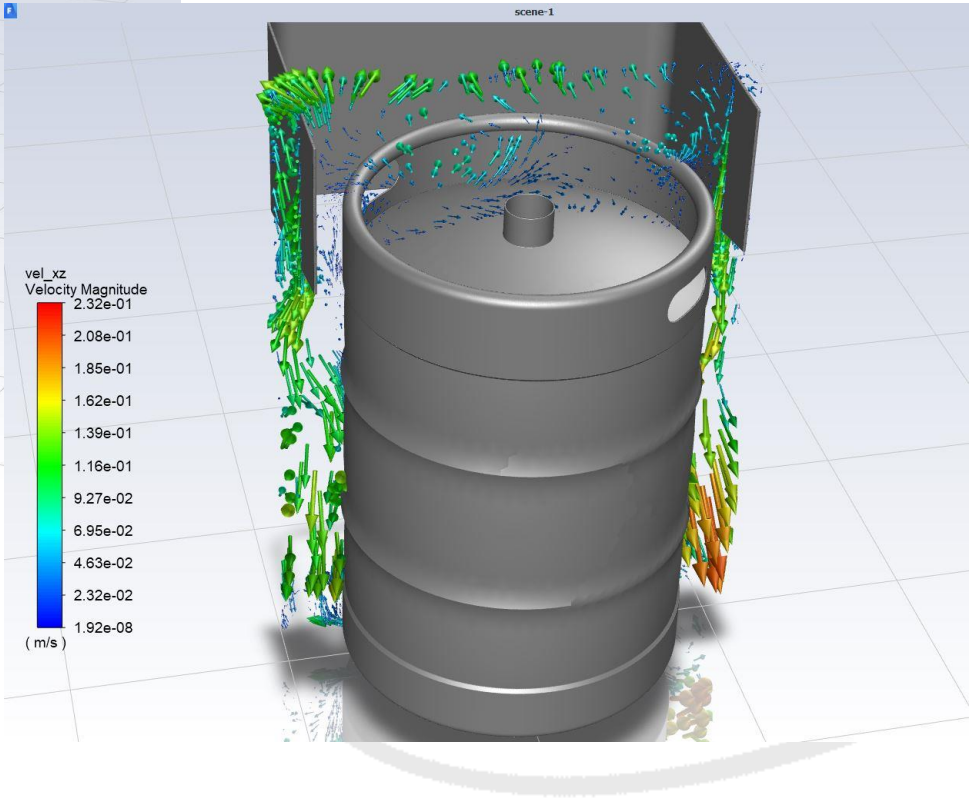
Click to animate

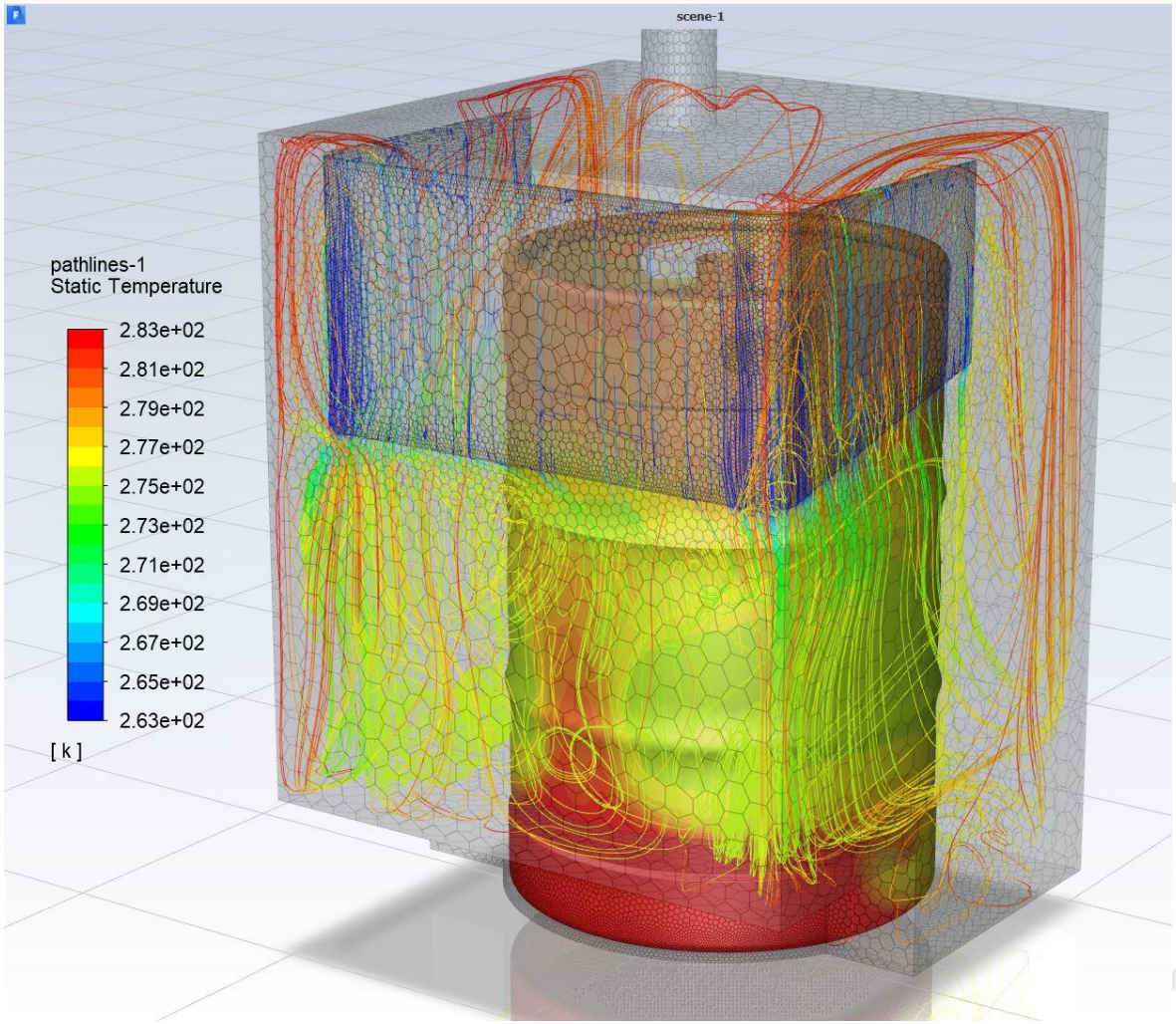


Fluent Results





Fluent Results



Fluent Results

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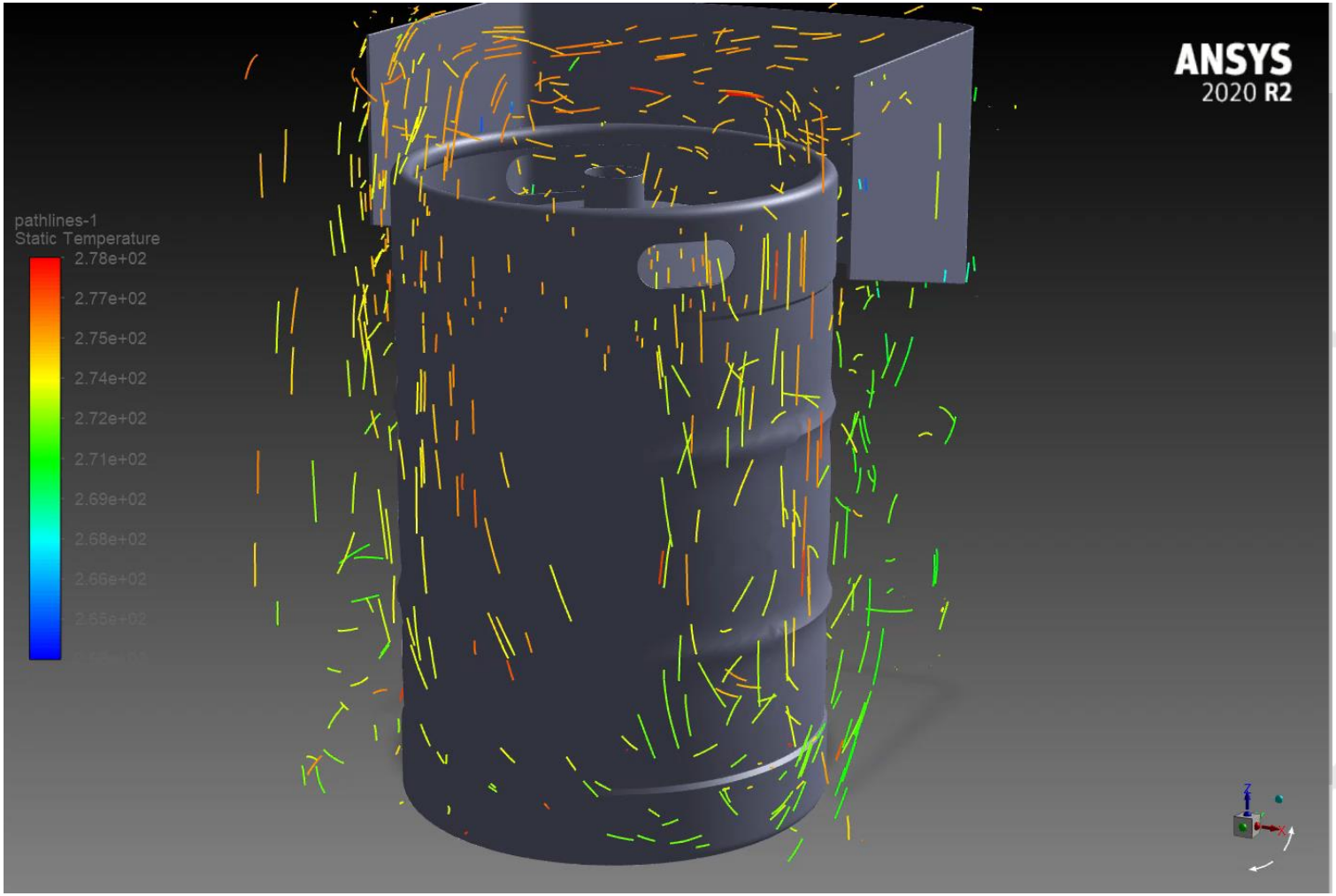
Click to animate



Work In Progress
FloCAD-Fluent Coupling

- Combine 1D and 3D fluid flow modeling
  - Complimentary solution strategies
    - 1D is fast, perfect for system level modeling
    - 3D is detailed and captures complex physics, but computationally expensive
  - 3D level of detail in an entire system level model is intractable
  - 1D level of detail may be missing important physics
- Use each method where appropriate in a coupled simulation
  - Each has a different, but useful view of the process

1D-3D Fluid Coupled Applications

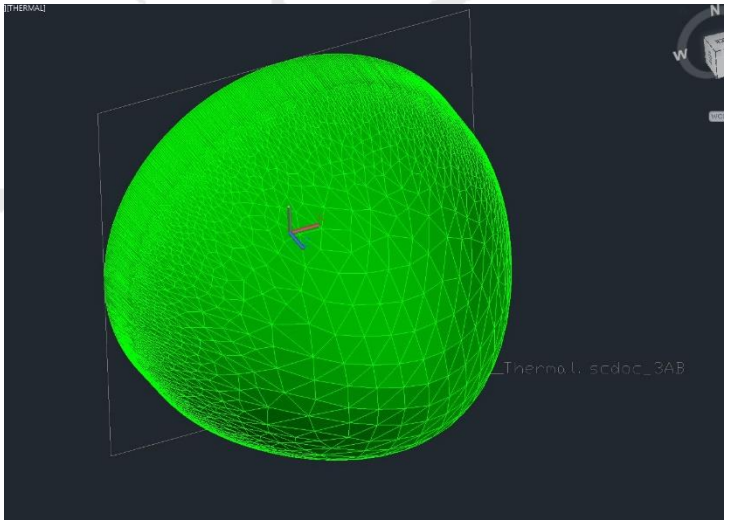
- Valve instability due to system level interactions
  - Fluent solves valve dynamics, FloCAD for system model
  - A response surface model of a 3D component is not always appropriate, there can be unexpected system level influences
- Pressurization injector/anti-swirl baffle
  - Fluent solves in-tank
  - FloCAD solves upstream/downstream
  - Thermal Desktop solves tank wall and environment
- Crew comfort
  - FloCAD/Fluent ECS
  - Orbital heating
  - Human body model

Current Activities

- ANSYS is currently modifying Fluent via UDF's to connect inlet and outlet zones via System Coupling
  - Maintains desired "black box" connection via SyC
- New FloCAD objects are being developed to represent Fluent inlets and outlets in a Thermal Desktop model
  - Will maintain abstraction for schematic layout, exact 3D locations not always desired
- Coupling approach has been verified
  - Upstream supplies mass flow rate and temperature
  - Downstream supplies pressure

FloCAD Scalar to 2D Fluent Mesh

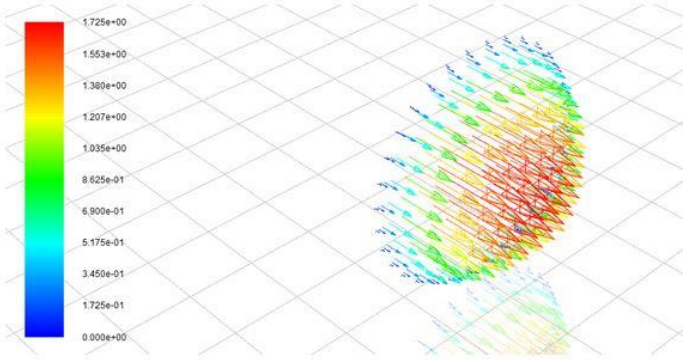
- System Coupling requires a 2D mesh for the interface
- A fully developed profile generator was developed that expands scalar FloCAD data based on Reynolds number, laminar Nusselt number, pipe radius, average velocity, and mean/wall temperatures
- Reconstruction and integration will be done in the coupler
  - FloCAD scalars -> 2D mesh
  - 2D Fluent mesh -> scalars



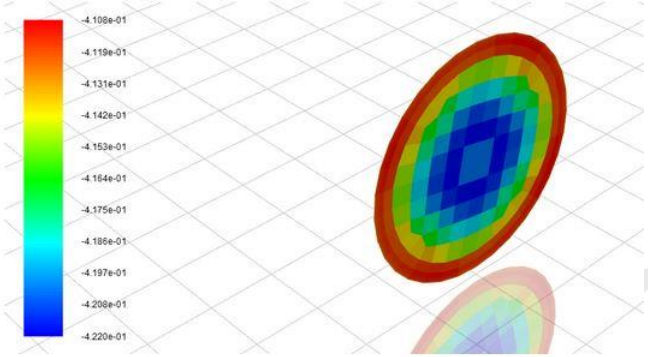
2D Fluent Mesh to FloCAD Scalar

- Fluent inlet and outlets connected to System Coupling

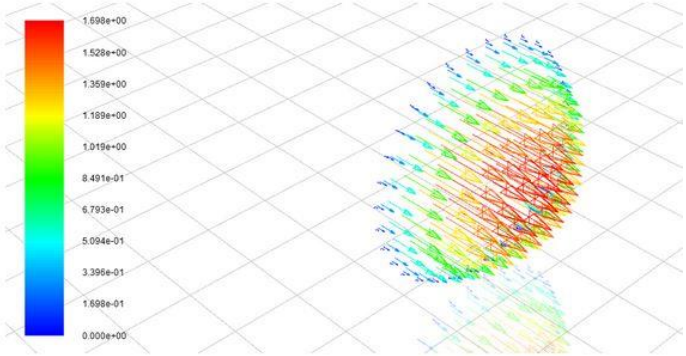
Velocities from upstream pipe outlet:



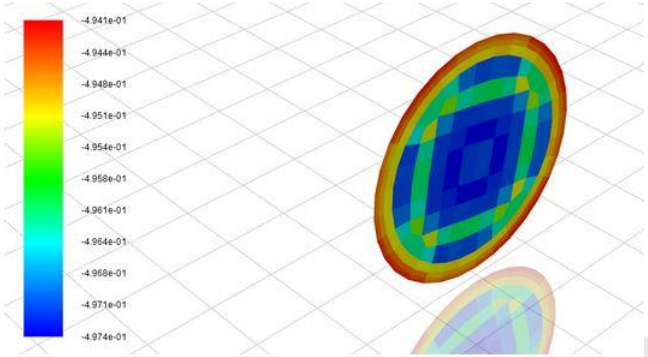
and the static pressures from the the same downstream inlet:



are passed to the downstream pipe inlet:



are passed back to the upstream pipe's outlet:



Acknowledgements

- A very big thank you to the ANSYS partner team
  - Mike Rowen
    - Manager, Partner Program
  - Oleg Churnukhin
    - Lead Developer, System Coupling
  - Adam Anderson
    - Principle Fluent Technical Support and Development

Summary

- CHT capability will be available in Version 6.2 release Q4
  - Easy to use –
    - Proficiency with Fluent and Thermal Desktop recommended
    - System Coupling well documented and supported
  - Advanced coupling algorithms for stability and speed
  - Built-in feature, no additional license
- 1D <–> 3D fluid coupling in progress and proceeding well
  - Too early to commit to 6.2, but a possibility
- CHT available as a beta for interested parties prior to 6.2
  - Discussions always welcome
- Hands-on labs planned for TFAWS 2021

Questions

- Q & A
- Thank you!